

India-based Neutrino Observatory¹

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Abstract:An introduction to India-based Neutrino Observatory and a brief status report are presented. The two possible sites are described along with their special advantages. The proposed detector and its physics capabilities for atmospheric neutrinos and long-base-line experiments are discussed.

Introduction: Historically, the Indian initiative in Cosmic Rays and Neutrino Physics experiments goes back several decades. In fact, atmospheric neutrinos were first detected in the Kolar Gold Fields (KGF) experiments in India almost 4 decades ago. KGF were one of the deepest mines in the world. When the cosmic ray muon experiments were set up at deeper and deeper levels in the mines, the counters fell silent at a particular depth. It was realised that at those depths and beyond, atmospheric neutrinos could be detected. They went ahead and detected them. That was in 1965 and it was the beginning of atmospheric neutrino physics. However, the deeper levels of KGF are now closed.

Sometime ago it was decided to revive neutrino experiments in India and a major collaboration involving about 12 institutions has been formed. This is the India-based Neutrino Observatory (INO) project. More than 60 scientists have already joined and feasibility studies are in progress. Two possible sites for the underground laboratory have been located. A magnetised tracking iron calorimeter of 30-50 Kton with RPC detector elements is under design and prototyping. In the first stage the aim will be to study atmospheric neutrinos and in the next stage this detector is envisaged as the far detector for a long-base-line neutrino experiment. International collaboration is invited.

A Tale of Two Sites: We give more details about the two sites: PUSHEP (Lat 11.5 deg N, Long 76.6 deg E): Under the Nilgiri Mountains in South India; adjacent to a hydel project PUSHEP (Pykara Ultimate Stage HydroElectric Project); vertical overburden in the range 1.3- 1.4 Km and all-around cover of more than 1 Km; laboratory cavern to be dug at the end of a tunnel of length about 2 Km; located in the Southern Peninsular Shield; uniform rock medium of mean density 2.8 gms/cc; seismic zone 2; close to the Cosmic Ray Laboratory of TIFR and the Radio Astronomy Centre of TIFR, both in the hill station Ooty; close to big cities (with airports) like Coimbatore and Bangalore, with excellent industrial and academic infrastructure. Detailed survey of the region is complete.

RAMMAM (Lat 27 deg N, Long 88 deg E): Under the Himalayas, in the Darjeeling District of West Bengal; a tunnel of 3-5 Km can reach an overburden of 1.5-1.85 Km or even more; seismic zone 4; detailed survey is in progress.

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Both sites are excellent for an underground neutrino laboratory. After a critical evaluation of the relative advantages and disadvantages of both sites with respect to the physics goals and practical aspects, one of them will be chosen.

Detector: To start with, it is proposed to build a magnetised tracking iron calorimeter, based on Monolith design. It will consist of 140 layers of 6 cm thick iron plates interleaved with 2.5 cm air gap containing the active detector elements. The dimensions will be 15 m X 32 m X 12 m (ht) and the weight about 30Ktons. The detector elements will be glass RPC's (Resistive Plate Chambers), with nanosecond timing, to provide up-down discrimination. The detector will be sensitive to muons and other charged particles.

A magnetic field of 1-1.3 Tesla will be an important feature of the detector. This will provide efficient energy-momentum resolution and also charge-identification which is an essential requirement for a far-end detector in a long-base-line experiment.

The detector will be constructed in a modular fashion, so that additional modules can be added in future, to augment its capability for the long-base-line experiment and other experiments. Emulsion sandwich is also being considered as a possibility with the aim of detecting the tau leptons.

Physics possibilities at INO: From the long term point of view, a neutrino detector located in India will have several advantages. A solar neutrino detector at a low latitude (PUSHEP at 11.5 deg) will detect solar neutrinos passing through the core of the Earth. A geoneutrino detector at RAMMAM will detect the geoneutrinos from the unusually thick continental crust below the Tibetan plateau. Very long base lines from neutrino factories become possible with detectors located in India. The baseline lengths from a neutrino factory at JHF (Japan) to PUSHEP or RAMMAM are 6,595 Km (31 deg) and 4,880 Km (22 deg) respectively, the brackets showing the required dip angle of the muon decay pipe. The corresponding numbers from a neutrino factory at CERN are 7,145 (34) and 6,890 (33) and from a factory at Fermilab are 11,300 (62) and 10,500 (55). The importance of multiple number of long base lines for neutrino physics is now well recognised. Some of the above distances are close to the "magic" baseline length of 7,200 Km. The very long base line of 11,300 Km passes through 3000 Km of Earth's core and hence is likely to play a major role in future neutrino tomography of the Earth.

In phase I, INO will be studying atmospheric neutrinos. The aim will be to establish neutrino oscillations by showing the rise in the neutrino flux after the minimum and to reduce the present uncertainty in the value of Δm_{32}^2 . In phase II, INO can play the role of the far detector in a long-base-line experiment. The major tasks in this phase would be probing θ_{13} , determination of the sign of Δm_{32}^2 and gaining a first glimpse of the CP violating phase δ .

We shall now show a few results of preliminary calculations by Raj Gandhi and Anindya Datta on the physics capabilities of INO both in phase I and phase II. The inputs used are muon detection threshold of 2 GeV and muon energy resolution of 5 percent. All measurements in phase II involve wrong sign muon detection and so

backgrounds are low.

Fig 1 shows the up/down ratio of atmospheric ν as a function of L/E for 200 Kton-yr of operation of the INO detector. It is clear that oscillations can be established.

Fig 2 gives the reach of $\sin \theta_{13}$ for nu factory experiments as a function of the muon detection threshold energy. The reach is defined as the value that will yield 10 signal events (wrong sign muons) for a given kT-yr exposure. We have shown the plots for Japan-RAMMAM and Fermilab-PUSHEP baselines.

Fig 3 shows the number of wrong-sign muon events as a function of Δm_{23}^2 for three base lines from a neutrino factory in Japan, the detector being at Beijing, Ramman or PUSHEP. The sign discriminating capability for either of the two sites Ramman or PUSHEP is clearly demonstrated.

Because of lack of space we shall not show the graphs for the CP violating phase, but calculations have been done for the ratio of wrong-sign muon events for a run with negatively charged muons in the storage ring to that for a run with positively charged muons. Although the CP violating effect is weak for the Japan-PUSHEP baseline, it is clearly present for the Japan-Rammam baseline.

Finally, it must be emphasised that we need the support and cooperation of neutrino enthusiasts all over the world. International collaboration for the INO project is invited. Naba Mondal (nkm@tifr.res.in) is the spokesperson for the project. More information on INO is available at the INO web-site $\langle\langle$ www.imsc.res.in/~ino $\rangle\rangle$.

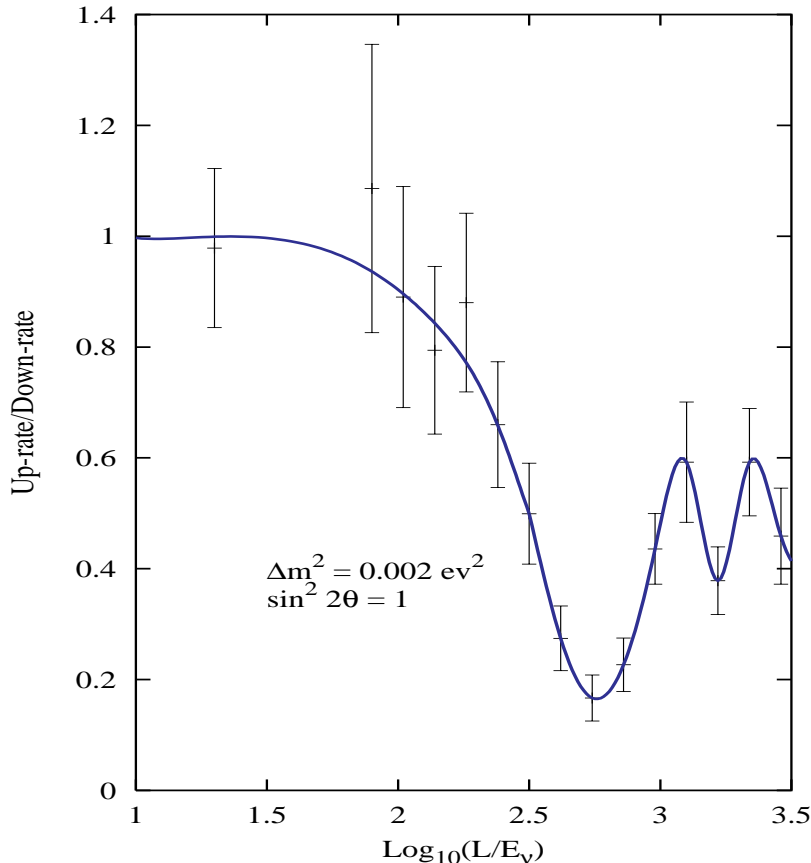


Figure 1: The up/down ratio of atmospheric ν vs L/E for 200 Kton-year.

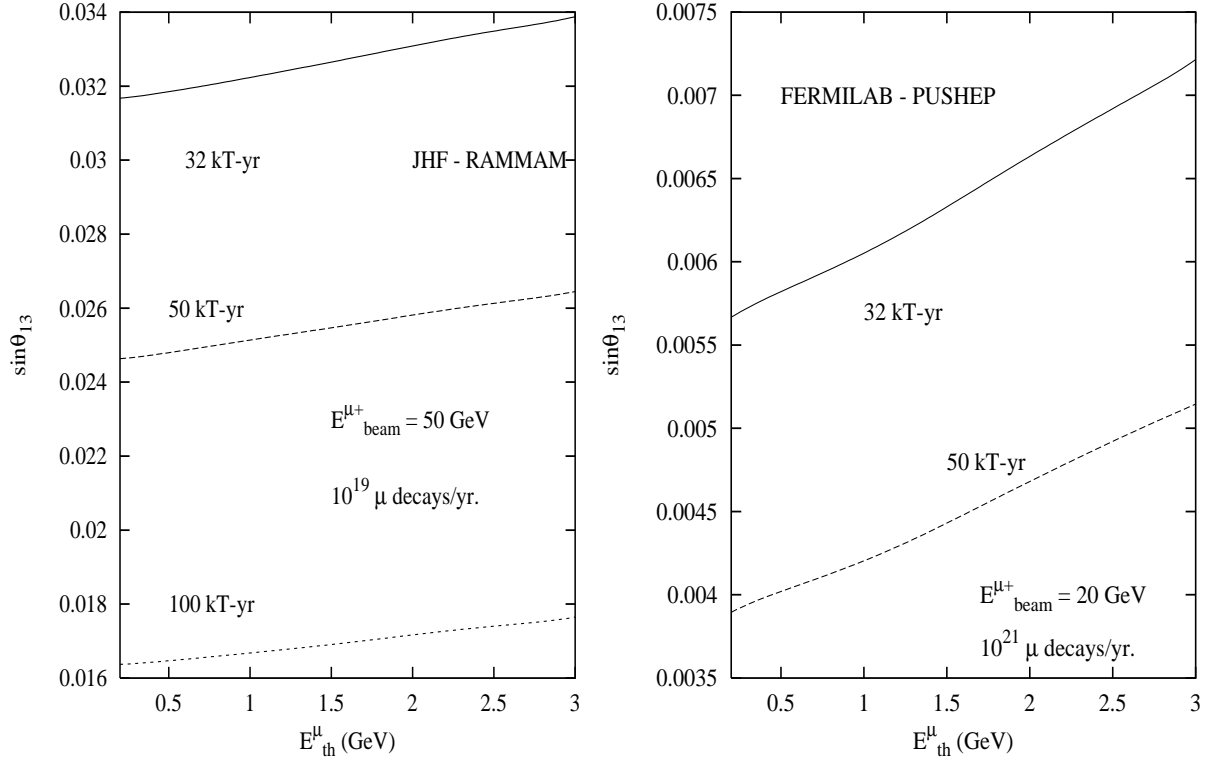


Figure 2: $\sin\theta_{13}$ reach as a function of the muon threshold energy. Left panel is for JHF to Rammam baseline. Right panel is for Fermilab to PUSHEP baseline.

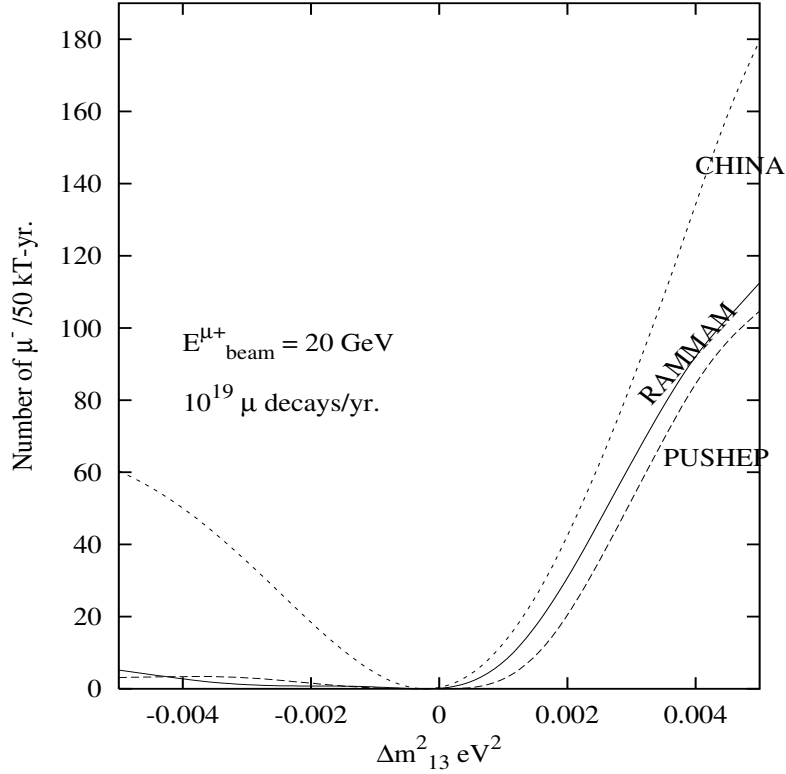


Figure 3: The number of wrong-sign muon events vs Δm_{23}^2 corresponding to baselines from JHF to Beijing, Rammam and PUSHEP.